DEPARTMENT OF
ECOLOGY
State of Washington

Lead and Other Metals in Traffic Paint in Washington State

Final Report

May 2015
Publication 15-04-018

Publication and Contact Information

This report is available on the Department of Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1504018.html

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Final Report

Hazardous Waste & Toxics
Reduction Program (HWTR)
Traffic Paint Team

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Acknowledgements

The Hazardous Waste and Toxics Reduction Program at the Department of Ecology wishes to thank the following people for their contributions to help complete this multi-year project: Mark Benedict, Lynn Coleman, Paul Fabiniak (Paint JAG[1] lead), Scott Lamb, Alice North, Mari Novak, Rolfe Parsloe, Darin Rice (PMT sponsor). Project management of the final phase of the project was completed by Nancy Winters. Nancy, Rolfe Parsloe, and Paul Fabiniak completed the sampling. The hard work and diligence of all of these people made this project a success.

[1] Job Alike Group

1.0 Introduction

In 2011 and 2012 as part of a wider effort to assess and reduce the use of lead and other metals, the Washington Department of Ecology (Ecology) received conflicting statements and information on whether leaded traffic paint is still in use. Some paint industry representatives and facilities stated that leaded traffic paint was no longer in use. The Washington Department of Transportation (WSDOT) contract specification for solvent-based traffic paint has required “no lead” for a number of years. However, contractors offered leaded paint to Ecology and at least one other public entity in western Washington when striping paved surfaces. In these two situations, metals information was based on the Material Data Safety Sheets (MSDSs) provided by the contractors.

For the purposes of sampling for this report, leaded paint is defined as greater than 600 parts per million (ppm) lead in the dried paint film. WSDOT specification for low volatile organic compound (VOC) solvent-based traffic paint limits lead to less than 600 ppm and chromium to less than 50 ppm (WSDOT, 2010). However, there is no legal requirement in the state to use this specification or traffic paint meeting these criteria. Other entities are free to use the specification or not.

In 2013, Ecology conducted random field tests in Thurston County to determine if applied traffic and zonal striping paint was above or below the 600 ppm level. Sampling focused primarily on yellow paint due to the historic use of lead chromate in yellow paint for bright color. In addition to yellow paint, staff sampled white, red, and blue markings where present. Staff later sampled additional locations in King County, City of Yakima, and City of Spokane for a broader geographic sampling.

An x-ray fluorescence (XRF) unit was used to conduct 79 analyses, mainly in parking lots. Of those, 59 exceeded 600 ppm lead and 41 exceeded 10,000 ppm lead. The highest result was 42,000 ppm lead. While some of the samples were obviously older samples or had multiple layers of paint, Ecology also measured parking complexes that were newly paved and striped for the first time in that year. Those samples contained yellow paint with 24,000 to 29,000 ppm of lead. At the lower end of the spectrum, five parking lot samples showed concentrations of lead less than the limit of detection (LOD), while another five parking lot samples ranged between the LOD and 600 ppm. Four paint striping sites along streets measured less than the 600 ppm threshold.

Limited field tests confirmed that traffic paint containing lead greater than 600 ppm was used in some Washington locations as recently as 2013. However, the tests did not provide sufficient data to estimate a total amount of leaded traffic paint used in any of the cities or counties tested.

To gain additional information, Ecology contacted Ennis-Flint, the current holder of the state solvent-based traffic paint contract. The company is a major provider of traffic and other paints in the United States. The company has manufactured both leaded and lead-free traffic paint. Ennis stated they have slowly reduced lead in their products for 20 years, beginning with high-volume products where the cost of reformulating would provide the best cost benefit. Solvent-based traffic paints, which represent a smaller part of their products, were converted to completely lead-free products later. The company decided to eliminate lead use in all of their 14 U.S. manufacturing facilities as of January 1, 2014. (Personal communication, 2014).

Ecology wanted to conduct a more in-depth evaluation of traffic paints that are for sale in the state. Staff wanted to compare XRF analyses of paint samples to laboratory analyses and do additional field testing. Because the XRF unit can provide concentration data on multiple metals simultaneously, Ecology staff decided to assess not only lead and chromium, but also cadmium, copper, and zinc. Ecology's concern about these five metals focuses on their toxicity to human health and the environment. Metals in traffic and zonal paint wear and chip off and they can become airborne or waterborne.

For lead and chromium, the focus is predominantly on human exposure. Exposures to lead have been linked to learning disabilities and behavioral problems in young children and elevated blood pressure, and nervous system damage in adults (Ecology and Health, 2009). Chromium (especially hexavalent chromium) can irritate the respiratory tract, resulting in airway irritation, airway obstruction, and lung, nasal, or sinus cancer. During dry periods, metal constituents in traffic paint can wear and sorb onto dust particles, exposing humans through inhalation. These two metals are also toxic in aquatic systems.

Stormwater can carry paint and its constituents into fresh and marine waters. Ecology determined that surface water runoff was the greatest contributor of lead, copper, and zinc to the waters of the Puget Sound basin (Ecology, 2011). Copper and zinc are toxic to fish and aquatic plants. Even at very low concentrations, copper can disrupt the Coho salmon's olfactory senses. Zinc fouls fish gills, ultimately causing suffocation. Cadmium is toxic to humans, fish, and other aquatic species at very low concentrations.

2.0 Objectives and Study Design

2.1 Objectives

Ecology designed this study to achieve four objectives. The study:

1. Determined whether the traffic paint samples of products assessed by Ecology have lead or chromium concentrations above 600 and 50 ppm dry weight, respectively (Table 1). Paints sampled included those sold and applied in the latter half of 2014 or obtained from

manufacturers or vendors in 2014 and 2015. Paint samples included only yellow solvent-based traffic paint, except for one sample of yellow non-solvent-based paint (CC-01).

2. Compared the analytical laboratory results with the results of XRF measurements of paint and MSDS information for lead and chromium for all paint samples obtained.

3. Determined the thickness of lead-free paint applied over leaded paint necessary to attenuate (decrease) the lead concentrations measured by the XRF unit.

4. Obtained XRF analysis of paint applied in parking lots in 2014 to compare the results to those from the laboratory analyses, the XRF results, and the XRF results from a field study of paint applied in parking lots and with the results of the 2012-13 field study.

Table 1. Target Chemicals, Analytical Methods, and Reporting Limits

Analytes	Concentration of interest (ppm dry)	Analytical Method	Reporting Limit* (mg/Kg[a])
Lead	600	EPA 200.8	1.5
Chromium	50	EPA 200.8	1.3
Cadmium	Method Detection Limit	EPA 200.8	1.0
Copper	Method Detection Limit	EPA 200.8	2.5
Zinc	Method Detection Limit	EPA 200.8	5.0

[a] mg/Kg = milligram per kilogram, equivalent to ppm

2.2 Study Design

Addendum #2 of the Quality Assurance Project Plan (QAPP) describes the details of sampling and analysis, while these subsections provide a brief overview.

Ecology obtained traffic paint samples from paint manufacturers and local vendors in Washington State and tested both solvent-based and non-solvent-based yellow paints. Paint manufacturers included Ennis-Flint, Sherwin-Williams, Kelly Moore, Grainger- RAE, Rhodda Paint, Miller Paint, and Columbia, as well as aerosol sprays manufactured by Rustoleum, Fastenal-Rustoleum, Ace Hardware, Do-It-Best, and Krylon used for striping by do-it-your-selfers. Most of the paint samples were manufactured in 2014. Ecology staff submitted the paint samples to its Manchester Environmental Laboratory for analysis of metals.

2.2.1 XRF and Laboratory Analyses of Paint Samples and MSDS Comparisons

Ecology assessed the metals content of the dried paint samples using the Niton XL3t XRF analyzer for comparison with the laboratory analyses and the MSDS review. If XRF screening showed copper, or zinc above the limits of detection of the XRF unit, staff asked the laboratory to analyze for these additional metals.

Ecology assessed metals concentrations of the paints obtained by purchase or from vendors. The laboratory analyzed all of the paints for lead, chromium, and cadmium and a few samples for zinc, based on the XRF results showing the presence of zinc.

Ecology compared paint sample data from XRF analysis, laboratory analysis, and MSDSs.

2.2.2 Attenuation of Lead Measurements in XRF Analyses with Paint Layers

For the lead attenuation portion of the study, Ecology staff formulated leaded paint of the following nominal concentrations: 10,000, 3,300, 1,100, 370, and 123 mg/Kg dry weight of lead. Staff applied each concentration as a base layer to a different piece of sheet metal. As the subsequent layers of unleaded paint were added to each designated area and dried, staff measured their thicknesses with a micrometer in five locations. Using the Niton XL3t XRF unit, staff conducted XRF analysis in approximately the same five locations where the thicknesses had been measured. Staff sent samples of the leaded-paints used in this part to the laboratory for confirmation of the lead concentrations.

2.2.3 Field Measurements

Using an Olympus InnovX Systems Alpha XRF unit, staff measured yellow paint striping at three in-situ locations in Eastern Washington. The previous summer, contractors had applied yellow traffic striping at these three locations. For two of these locations (the two parking lots), the contractor applied paint over clean pavement. At the third location, the contractor had reapplied paint over existing traffic striping. At each location, Ecology took between three and five XRF readings of the yellow paint at approximately one-foot intervals. Ecology also took XRF readings of the bare pavement.

3.0 Deviations from the QAPP and Data Quality

Study implementers deviated from the Quality Assurance Project Plan (QAPP) in a few minor ways, as described below:

After completion of the QAPP, the Traffic Paint Team decided to focus this study by sampling only yellow traffic paint. The study focused on yellow paint due to the historic use of lead chromate in yellow paint for bright color. The study also focused on predominantly solvent-based paint because of their common use. Only one sample was not a solvent-based paint.

The laboratory used EPA[2] Method 200.8 for the analyses of metals rather than EPA Method 6010. EPA Method 200.8 is generally a more sensitive method. The laboratory's analyses met all method detection limits specified in the QAPP. The laboratory's analyses also met all reporting limits specified in the QAPP, except for zinc. The reporting limits for zinc was 5.0 mg/Kg, rather than 2.0 mg/Kg. This did not affect the results.

For one of the samples, AH-1, the XRF detected 30 mg/Kg of zinc. The QAPP specified that all XRF detections of zinc be sent to the laboratory for confirmation. Ecology staff failed to have the sample analyzed by the laboratory for zinc. Instead, staff inadvertently sent sample SW-07 for analysis of zinc.

For the portion of the study assessing attenuation of lead reading for the XRF, staff attempted to apply paint in layers with a mini-roller or paint brush to create a dry film thickness of approximately 15 mils. However, due to the high viscosity of the paint, staff found that the paint was more uniformly applied by pouring it onto the surface and leveling it by tilting the metal surface. This resulted in greater thickness for each paint layer than anticipated. Staff measured the paint thicknesses in five locations for each layer and each leaded-paint concentration. Thus, the data were deemed useable to assess the relationship between thickness and lead attenuation.

Ecology staff used a different XRF unit for the field study (an Olympus InnovX Systems Alpha) rather than the Niton XL3t XRF unit used for the in-house study because the Niton unit (on loan from the manufacturer) was not allowed out of the building. Staff were less familiar with this unit and were not able to trouble-shoot when the XRF unit froze up in the field. Thus for one site, staff were unable to obtain XRF readings for the bare asphalt. However, because the lead concentrations in the paint at that site were similar to the bare asphalt at the site a mile away, the data were useable.

Other than these exceptions, all analyses met the reporting limits (RLs) and other measurement quality objectives. The data are useable for this report.

[2] United States Environmental Protection Agency

4.0 Results and Discussion

This section presents:

1. Results of XRF and laboratory analyses of paints.
2. Comparison of XRF and laboratory data with MSDSs.
3. Lead attenuation determinations with increasing layers of paint using the XRF.
4. Field measurements and comparisons with the previous study.

4.1 XRF and Laboratory Analyses and MSDS Comparisons

Neither the XRF nor the laboratory detected lead greater than 600 mg/Kg in any of the 29 samples tested, all of which were manufactured in 2014 for sale in Washington. Data from the XRF and laboratory analyses for lead, chromium, cadmium, copper, and zinc in the paint samples, along with other information about the paints sampled are available in Appendix A.

The XRF did not detect lead in any of the paint samples. The LOD for lead is 4 mg/Kg . (Table 2 lists the manufacturer's LODs for lead and the other four metals.) The laboratory detected lead in all of the 29 paint samples, but at very low concentrations ranging from 0.51 to 5.68 mg/Kg dry weight (Table 3). The laboratory reported concentrations predominantly below the LOD for the XRF. None of the samples exceeded the 600 ppm threshold for lead.

Table 2. Manufacturer's levels of detection for five metals

Metal	Level of Detection (mg/Kg dry wt.)
Lead	4
Cadmium	15
Chromium	*
Copper	15
Zinc	15

*Level of detection not specified by manufacturer

Table 3. Comparison of XRF and Laboratory Metals Concentrations in paints sampled

Sample Number	Percent solids (lab)	Lead (ppm-dry wt)		Chromium (ppm-dry wt)		Cadmium (ppm-dry wt)		Copper (ppm-dry wt)	Zinc (ppm-dry wt)	
		XRF	Lab	XRF	Lab	XRF	Lab	XRF	XRF	Lab
SW-01	73.9	ND	**2.41**	ND	2.44	ND	**0.136**	ND	20	**13.6**
SW-02	73	ND	**1.28**	ND	0.85	ND	0.133U	ND	ND	NM
SW-03	76.3	ND	**1.37**	ND	0.29	20	0.128U	ND	ND	NM
SW-04	71.5	ND	**0.94**	ND	0.52	ND	0.135U	ND	ND	NM
SW-05	99.8*	ND	**5.68**	ND	2.99	ND	**0.338**	ND	ND	NM
SW-06	73	ND	**4.43**	ND	1.36	ND	**0.297**	ND	ND	NM
SW-07	78.7	ND	**3.13**	ND	1.13	ND	**0.324**	ND	ND	**10.4**
AH-1	44.1	ND	**0.52**	ND	9.07	20	0.212U	ND	30	NM
RA01	68.2	ND	**2.06**	ND	2.52	ND	**0.447**	ND	ND	NM
RA03	38.4	ND	**1.97**	ND	8.52	ND	0.237U	ND	ND	NM
KM01	65.6	ND	**1.11**	ND	1.99	ND	0.144U	ND	ND	NM
IX01	51.8	ND	**0.79**	ND	0.41	ND	0.173U	ND	30	**41**
GR01	26.2	ND	**1.41**	ND	0.95	ND	0.351U	ND	ND	NM
GR03	79.4	ND	**2.89**	ND	1.49	ND	0.118U	ND	ND	NM
GR05	69.1	ND	**2.10**	ND	1.61	ND	0.140U	ND	90	**64.7**
GR07	71.6	ND	**2.03**	ND	1.32	ND	0.136U	ND	ND	NM
GR09	72.4	ND	**1.86**	ND	1.55	ND	0.126U	ND	47	**58.5**
FR01	68.2	ND	**1.85**	ND	2.35	ND	0.131	ND	ND	NM
EF01	68.9	ND	**2.39**	ND	3.32	ND	**0.325**	ND	ND	NM
EF03	69.6	ND	**1.67**	ND	2.48	ND	**0.275**	ND	ND	NM
EF05	70.3	ND	**1.45**	1,200	2.59	ND	0.134U	ND	ND	NM
EF-07	72.7	ND	**1.17**	1,050	2.35	ND	0.129U	ND	ND	NM
EF-08	70.0	ND	**4.18**	ND	4.13	ND	**0.188**	ND	ND	NM
RU-01	27.3	ND	**0.76**	ND	3.79	ND	0.346U	ND	ND	NM
RU03	50.1	ND	**2.77**	ND	0.80	ND	0.184	ND	ND	NM
RU05	22.9	ND	**0.53**	ND	1.19	ND	0.414	ND	ND	NM
KY01	30.8	ND	**5.64**	4,900	4.57	ND	0.313	ND	ND	NM
DB01	56.9	ND	**0.72**	ND	1.05	ND	0.166U	ND	ND	NM
CC-01	73.8	ND	**3.05**	ND	1.50	ND	**0.266**	ND	ND	NM

ND = Not detected
NM = Not Measured
U = Not detected above reporting limit
*submitted as a dried sample

The XRF results were not as consistent for the chromium measurements. The XRF unit detected chromium in three of the 29 paints sampled. The XRF recorded these three chromium concentrations at very high levels between 1,050 and 4,900 mg/Kg. Ennis Flint manufactured two of these, while Ace Hardware manufactured the third. The other three Ennis Flint samples did not exhibit concentrations of chromium above the LOD. The laboratory reported low concentrations of chromium for these three samples reported, ranging from 2.35 to 4.57 mg/Kg. Thus, these samples may have had a compound in the paint that caused matrix interferences with the XRF unit. The laboratory detected chromium in all paint samples but at concentrations ranging from 0.29 to 9.07 mg/Kg dry weight. None of the samples exceeded the 50 ppm threshold for chromium. The XRF analysis may not be a consistently accurate predictor of chromium in all paints.

The XRF unit detected zinc in five of the samples with concentrations that ranged from 20 to 90 mg/Kg. Two of these concentrations approached the XRF's LOD of 15 mg/Kg. The laboratory detected zinc in five of the five samples sent to the laboratory. Concentrations ranged from 10.4 to 64.7 mg/Kg dry weight (Table 3). A linear correlation was found from these five data points with a correlation coefficient (r^2) of 0.75. Thus, while Ecology staff did not send sample AH-1 to the laboratory for analysis of zinc, the fact that zinc was detected in the other five paints analyzed by the laboratory may indicate the presence of zinc in the AH-1 sample, but at a concentration of less than approximately 30 mg/Kg. No thresholds have been established for zinc in traffic paint.

The XRF unit detected cadmium in only two of the samples at concentrations of 20 ppm, slightly above the LOD for the XRF. The laboratory reported cadmium in 13 of the samples but not in either of the samples flagged by the XRF. The laboratory measured all concentrations less than 0.5 mg/Kg (Table 3). Because the laboratory measured cadmium concentrations substantially less than the XRF's LOD for cadmium, one would not expect the XRF's results to be a good predictor for low concentrations of this metal. Thresholds for cadmium in traffic paint have not been specified.

The XRF unit did not detect copper in any of the paint samples. No laboratory analyses were performed for copper. No thresholds are specified for copper in traffic paint.

None of the MSDSs reported any concentrations of lead or chromium (Appendix A), although MSDSs do not generally report concentrations of metals below the percent level (10,000 ppm). Comparison of the XRF data for lead and chromium with the MSDSs supported the MSDS information.

When Ecology compared concentrations of laboratory analyzed lead, chromium, and cadmium, all concentrations appear to be below concentrations generally reported on the MSDSs. The low concentrations of the metals observed in the laboratory data could have been a result of inadvertent contaminants in the paint formulation.

4.2 Attenuation of Lead Measurements in XRF Analyses of Paint Layers

Ecology staff formulated five different concentrations for leaded paint by adding lead carbonate to unleaded paint (Sherwin Williams A303) as specified in the QAPP. These were used for the attenuation portion of the study.

Ecology measured concentrations of lead in these samples both on the XRF and in the laboratory (Table 4). Because both the laboratory and XRF analyses reported values above the detection limits, Ecology could evaluate simple statistics for these five paint samples. The absolute value of the relative percent differences (RPDs, the differences between the two values as a percentage) between the XRF analysis and the laboratory analysis of each of these samples ranged broadly from 13 to 62%. The large RPDs for all samples except the 77 mg/Kg sample, indicate that the XRF should only be used as a broad screening tool. For example, an XRF operator may need to observe lead concentrations greater than approximately 900 mg/Kg in the field to feel confident that the originally applied paint was greater than the threshold lead concentration of 600 mg/Kg.

Table 4. Concentrations of lab- and XRF-measured lead and the RPDs

Lab Pb (ppm)	XRF Pb (ppm)	⎮RPD⎮ (%)
13,600	8,910	34.5
2,170	3,200	47.5
760	1,050	38.2
241	390	61.8
77	87	13.3

⎮RPD⎮ = absolute value of the relative percent difference

Even though Ecology found elevated RPDs, Ecology identified a linear correlation for the lower four lead concentrations with an r^2 value of 1.0, as depicted in Figure 1. When the highest formulated leaded paint concentration is added, the r^2 drops to 0.96 and the equation crosses the x-axis at a concentration of 631 mg/Kg, suggesting that the XRF is useful only as a relatively rough screening tool.

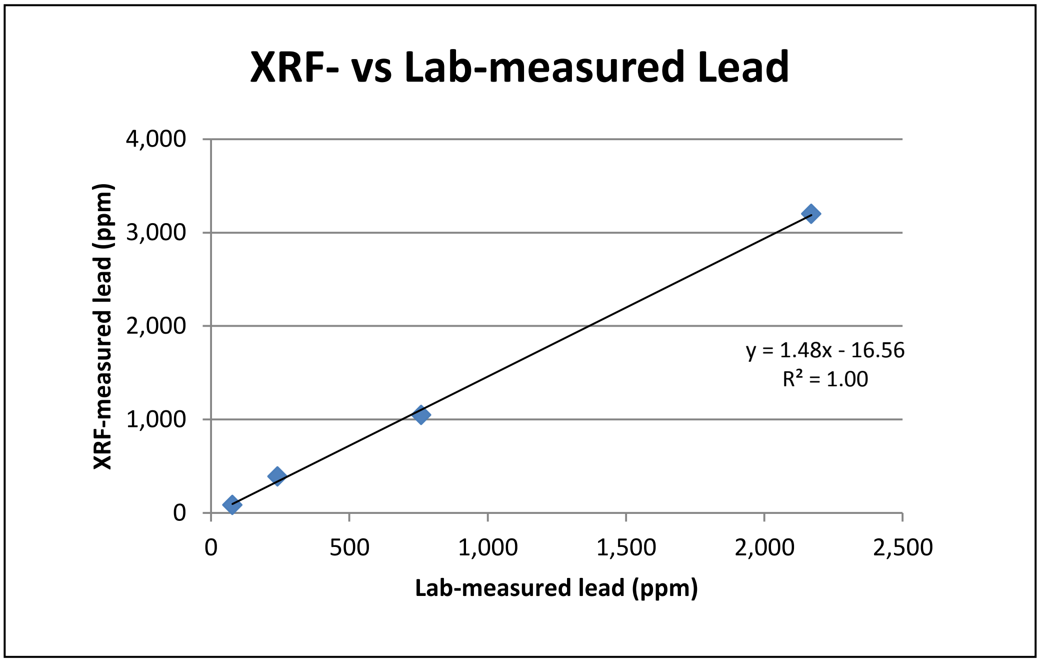

Figure 1. Correlation between lead concentrations measured by XRF and the laboratory.

Ecology staff made an interesting observation about the function of the XRF unit. The unit changed its output from percent of a metal to parts per million (ppm) randomly. The ppm reading provided greater precision. This feature is not operator-controlled.

Ecology staff applied paint to each of the five formulated leaded paints described in the preceding paragraphs on a different metal sheet, then painted between three and five layers of unleaded paint over the leaded paint. Ecology recorded the dry thickness of each paint layer at five locations for each of the five metal strips with a different concentration of underlying leaded paint. Figure 2 depicts the approximate locations of these measurements.

Leaded paint		Layer 1		Layer 2		Layer 3		Layer 4		Layer 5	
1	2	6	7	11	12	16	17	21	22	26	27
3		8		13		18		23		28	
4	5	9	10	14	15	19	20	24	25	28	30

Figure 2. Diagram of approximate locations of paint thickness and XRF measurements.

Ecology plotted the average cumulative paint thickness for each layer against the average XRF-measured lead concentration. Figure 3 presents this plot with lead concentration plotted on a log scale and paint thickness plotted on a linear scale. For each concentration, as Ecology applied subsequent layers of unleaded paint over the leaded paint, the ability of the XRF unit to detect the underlying leaded paint was attenuated. The attenuation showed an exponential decay with high correlation coefficients (r^2), ranging from 0.89 to 0.98 for the lowest and highest underlying leaded concentrations, respectively (Figure 3). Thus, with the application of additional layers of unleaded paint, the XRF measurements of lead concentration decreased exponentially (more rapidly with initial layers). But even for the thickest layers of unleaded paint (representing multiple layers of paint as applied in the field), the XRF detected some lead.

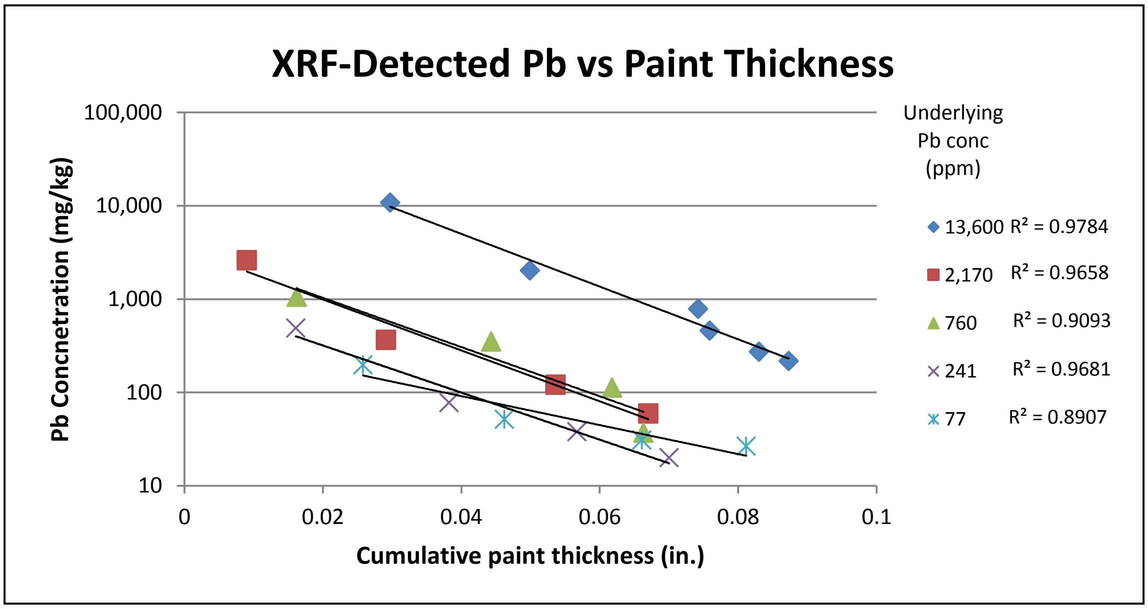

Figure 3. Average lead concentration as measured by the XRF vs average cumulative paint thickness.

One might be tempted to use Figure 3 to extrapolate from XRF concentrations measured in the field to their lead concentrations in the underlying paints. However, this is not recommended for at least two reasons. First, the correlations in Figure 3 represent only a small sample size. Second, under field conditions a number of factors are unknown: the lead concentration in the original paint, and numbers of layers of unleaded paint applied, and the thicknesses of each of those layers. Paint wear patterns may also be site-specific.

4.3 Field Measurements and Comparison with Previous Study

Ecology staff used the XRF to evaluate in-situ paint striping in two locations in Ellensburg, Washington and one location in Spokane, Washington. All three locations were striped in the summer of 2014. The traffic striping paint on Capitol at the intersection of Locust in Ellensburg appeared to have been applied at least three times based on visual observation. While in the parking lots of the Music Building at Central Washington University and Hub Sports Center in

Spokane, Ecology took the XRF samples over the single layer of paint. Table 5 presents the data read from the XRF unit at the three in-situ locations.

Table 5. XRF measurements of lead in yellow striping at three Eastern Washington locations.

Location	Station	Lead (ppm dry weight)
Yellow striped road divider at intersection of Capitol and Locust in Ellensburg, WA		
	CL-1	216
	CL-2	2,749
	CL-3	2,513
	CL-4	3,117
	CL-5	2,744
Bare asphalt at intersection of Capitol and Locust in Ellensburg, WA		
	CL-6	18
	CL-7	19
	CL-8	19
Yellow parking lot striping at Central Washington University Music Building Parking Lot - striped in 2014		
	MB-1	18
	MB-2	21
	MB-3	18
Yellow Striping at Hub Sports Parking Lot 19719 E Cataldo St Spokane, WA		
	HS-1	16
	HS-2	17
	HS-3	22
	HS-4	20
	HS-5	21
Bare pavement at Hub Sports Parking Lot 19719 E Cataldo St Spokane, WA striped in 2014		
	HS-6	16
	HS-7	15
	HS-8	17

From the XRF readings, the striping applied along Capitol in Ellensburg appeared to be leaded paint. However, based on the previous discussion of attenuation of lead measurements, the underlying paint striping likely influenced the XRF readings. Staff noted that the initial reading (CL-1) at the beginning of the stripe appeared to be either a single layer of paint with lower lead concentrations or underlying layers were substantially worn off before the recent paint application. This could account for the lower concentration at this station.

The other two locations were zonal striping. For these the yellow striping appeared to be a single layer of unleaded paint that approximated the background concentration.

The results of the 2013 in-situ paint striping study reported that of the 21 parking lot locations sampled in Thurston and King Counties, lead concentrations ranged from 1,000 to 42,000 ppm; and 47% of the sites sampled were greater than 20,000 ppm. Even where zonal paint had been applied within a year, the lead in the paint ranged from 24,000 to 29,000 ppm lead.

For those lead concentrations at the lower end of the spectrum in the 2013 study, five parking lot samples showed concentrations of lead less than the LOD, while another five parking lot samples were between the LOD and 600 ppm. Four samples of paint striping along streets were also less than the 600 ppm threshold.

The 2013 data also reported one instance of new overspray at 16 ppm lead, while an XRF analysis of multiple layers along that line reported 10,500 ppm lead. This would seem to indicate that the newer, over-sprayed paint was unleaded, while the underlying layers were leaded paint. They could also reflect variation in the level of wear in the underlying paint prior to re-application of unleaded paint.

Comparison of the findings of the 2013 study with those of this study seems to imply that new single layer applications of striping paint appear to be lower than the 600 ppm limit specified for state contracts. As observed at a few locations in 2013 and in this study (albeit a small sample size) recent applications of traffic and zonal paints seem to be using unleaded paint. Where high readings were observed using the XRF in the field, it is difficult to determine whether the locations were re-application of leaded traffic paint, or were re-application of unleaded paint over previously applied leaded paint.

5.0 Conclusions

The following conclusions can be drawn from the data:

The 29 paints manufactured for sale in Washington State and sampled in this study did not contain lead or chromium over the thresholds of 600 and 50 ppm, respectively. For those paints assessed, the paint manufacturers have successfully phased out the use of lead in traffic paints sold in the state of Washington. Thus, the state contract specifications along with other factors may be having the intended results.

Very few of the traffic striping paints contained measurable concentrations of cadmium or zinc.

In general, the XRF was not a sufficiently sensitive enough tool to detect lead concentrations with much accuracy. At the low concentrations observed in the new unleaded paint, the XRF unit did not have low enough detection limits. For approximately 10% of the chromium results, the XRF reported erroneously high concentrations that were not verified by the laboratory analyses. At best, the XRF unit served only as a rough screening tool for assessment of metals in traffic paint. However, newer XRF units may have refined settings for metals analysis in paints. These newer units may serve as a better screening tool for determining if samples were less than or greater than the concentration of interest at 600 ppm lead and 50 ppm chromium.

As the thickness of layers of unleaded paint applied over leaded paint increased, the XRF unit detected lower concentrations. Under laboratory conditions, the XRF unit still detected lead through several layers of unleaded paint that were thick in comparison to manufacturers' recommended specifications. The exponential decline in lead concentrations cannot be quantitatively applied to XRF readings in the field, because both the initial concentration of lead in the paint and the thickness of overlying unleaded layers are unknown. On the other hand, these results imply that as the newer, unleaded traffic paints cover the underlying leaded layers, less lead will be less exposed to the environment and potential stormwater runoff.

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Appendix A: MSDS, XRF, and Laboratory Data

Product Mfr	Product Name & No.	Mfr date	Expir. Date	Serial No.	Estimated Dry Time [C]	Aerosol y = Yes n= No	Ecology Sample No.	Tech Specs % Solids	Lab % solids	Lead		Chromium		Cadmium		Copper	Zinc		Notes
										XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	
Sherwin Williams	A303	2014	1 YR		DNH	n	SW-01	75%	73.9	ND	**2.41**	ND	**2.44**	ND	**0.14**	ND	20	**14**	#1Rolfe bought zinc 14 ppm
Sherwin Williams	TM5495	2014	1 YR		DNH	n	SW-02	75%	73	ND	**1.28**	ND	**0.848**	ND	0.13U	ND	ND	NM	#2Rolfe bought
Sherwin Williams	TM5127	2014	1 YR		DNH	n	SW-03	80%	76.3	ND	**1.37**	ND	**0.292**	20	0.13U	ND	ND	NM	#3Rolfe bought
Sherwin Williams	TM5645	2014	1 YR		DNH	n	SW-04	71%	71.5	ND	**0.94**	ND	**0.521**	ND	0.14U	ND	ND	NM	#4Rolfe bought
Sherwin Williams	TM5713	2014	1 YR	8000-55923	DNH	n	SW-05	92%	99.8 [A]	ND	**5.68**	ND	**2.99**	ND	**0.34**	ND	ND	NM	#5sampled at Hub Sports
Sherwin Williams	TM2161	2014	1 YR	DNH	B	n	SW-06	65%	73	ND	**4.43**	ND	**1.36**	ND	**0.30**	ND	ND	NM	#7manuf. Provided sample
Sherwin Williams	TM2153	2014	1 YR	DNH	B	n	SW-07	77%	78.7	ND	**3.13**	ND	**1.13**	ND	**0.32**	ND	ND	**10**	#8manuf. Provided sample
Ace Hardware	Ace solvent Based upside down marking paint		1 YR	1017680	B	Y	AH-1	30%	44.1	ND	**0.52**	ND	**9.07**	20	0.21U	ND	30	NM	#12Aerosol Rolfe bought
Rodda	Zone Marking Paint - Yellow Alkyd: 71 7188 1	2014				n	RA01	68%	68.2	ND	**2.06**	ND	**2.52**	ND	**0.45**	ND	ND	NM	Purchased by PF
Rodda	Traffic Marking Latex Paint - Yellow "Lead Free": 51 7188 1	2014				n	RA03	49%	38.4	ND	**1.97**	ND	**8.52**	ND	0.24U	ND	ND	NM	Purchased by PF
Kelly-Moore	Zone Marking Paint - Yellow "Lead Free" Waterborne: 1472131	2014				n	KM01	70%	65.6	ND	**1.11**	ND	**1.99**	ND	0.14U	ND	ND	NM	Purchased by PF
Insl-x	Zone Marking Paint - Yellow Latex: TP-2224	2014				n	IX01	Must call company	51.8	ND	**0.79**	ND	**0.408**	ND	0.17U	ND	30	**41**	Purchased by PF
Grainger-RAE	Zone Marking Paint - Yellow Latex: 4902-01	2014				n	GR01	66%	26.2	ND	**1.41**	ND	**0.946**	ND	0.35U	ND	ND	NM	Purchased by PF
Grainger-RAE	Zone Marking Paint - Yellow Alkyd: 2402-01	2014				n	GR03	78%	79.4	ND	**2.89**	ND	**1.49**	ND	0.12U	ND	ND	NM	Purchased by PF

Product Mfr	Product Name & No.	Mfr date	Expir. Date	Serial No.	Estimated Dry Time [c]	Aerosol y = Yes n= No	Ecology Sample No.	Tech Specs % Solids	Lab % solids	Lead		Chromium		Cadmium		Copper	Zinc		Notes
										XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	
Grainger-RAE	Traffic Marking Paint - Yellow Low VOC Alkyd: 7300-01	2014				n	GR05	70%	69.1	ND	**2.1**	ND	**1.61**	ND	0.14U	ND	90	**65**	Purchased by PF
Grainger-RAE	Zone Marking Paint - Yellow Chlorinated Rubber: 2494-01	2014				n	GR07	72%	71.6	ND	**2.03**	ND	**1.32**	ND	0.14U	ND	ND	NM	Purchased by PF
Grainger-RAE	Traffic Marking Paint - Yellow Low VOC Chlorinated Rubber: 7494-01	2014				n	GR09	72%	72.4	ND	**1.86**	ND	**1.55**	ND	0.13U	ND	47	**59**	Purchased by PF
Fastenal - Rustoleum	Traffic Zone Striping Paint - Yellow Alkyd: 2348	2014				n	FR01	55 -70%	68.2	ND	**1.85**	ND	**2.35**	ND	**0.13**	ND	ND	NM	Purchased by PF
Ennis -Flint	SB LF YEL OR HI VOC HOCY2	6/3/2014				n	EF01	68%	68.9	ND	**2.39**	ND	**3.32**	ND	**0.33**	ND	ND	NM	Purchased by PF
Ennis-Flint	HWVY3 Low VOC LF Yellow Solvent Paint	7/30/2014				n	EF03	70%	69.6	ND	**1.67**	ND	**2.48**	ND	**0.28**	ND	ND	NM	Purchased by PF
Ennis-Flint	SB LF YEL WA HI VOC HY842	8/14/2014				n	EF05	68%	70.3	1,200	**1.45**	1,200	**2.59**	ND	0.13U	ND	ND	NM	Purchased by PF
Ennis-Flint	SB LF Yel WA HI VOC HY*Y2	2014	1 YR	984762LF	B	n	EF-07	68%	72.7	1,050	**1.17**	1,050	**2.35**	ND	0.13U	ND	ND	NM	#15Ennis provided sample
Ennis-Flint	SB LF Yel OR VOC HOCY2	2014	1 YR	983782LF	B	n	EF-08	65%	70.0	ND	**4.18**	ND	**4.13**	ND	**0.19**	ND	ND	NM	#16Ennis provided sample
Rustoleum	Professional Inverted Marking Paint - HV Yellow: 266577	2014				y	RU01	20%*	27.3	ND	**0.755**	ND	**3.79**	ND	0.35U	ND	ND	NM	Purchased by PF
Rustoleum	Industrial Choice Inverted Striping Paint - Yellow: 1648838	2012				y	RU03	34%	50.1	ND	**2.77**	ND	**0.795**	ND	**0.18**	ND	ND	NM	Purchased by PF

Product Mfr	Product Name & No.	Mfr date	Expir. Date	Serial No.	Estimated Dry Time [C]	Aerosol y = Yes n= No	Ecology Sample No.	Tech Specs % Solids	Lab % solids	Lead		Chromium		Cadmium		Copper	Zinc		Notes
										XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	XRF dry (ppm)	XRF dry (ppm)	Lab dry (ppm)	
Rustoleum	Industrial Choice Water-Based Inverted Marking Paint - HV Yellow: 203034	2006				y	RU05	25%*	22.9	ND	**0.525**	ND	**1.19**	ND	**0.41**	ND	ND	NM	Purchased by PF
Krylon	Professional Solvent-Based Striping Paint - Yellow: K05911000	2012				y	KY01	34%	30.8	4,900	**5.64**	4,900	**4.57**	ND	**0.31**	ND	ND	NM	Purchased by AN
Do It Best	Striping Paint - Yellow: 794077	unknown				y	DB01	50%*	56.9	ND	**0.715**	ND	**1.05**	ND	0.166U	ND	ND	NM	Purchased by AN
Columbia	Hi-performance Coatings Fast Dry Acrylic Latex	unknown		17-125-CC		n	CC-01	75%	73.8	ND	**3.05**	ND	**1.50**	ND	**0.27**	ND	ND	NM	Purchased by MB
Rolfe SW	A303 derivative with lead carbonate added	NA	1 YR	DNH	B	n	STD-1	75%	72.6	8,910	**13,600**	ND	**2.26**	30	0.13U	ND	ND	NM	#1ARolfemade10K PB A303
Rolfe SW	A303 derivative with lead carbonate added	NA	1 YR	DNH	B	n	STD-2	75%	70.1	3,200	**2,170**	ND	**2.31**	20	0.13U	ND	ND	NM	#2ARolfemade3.3K PB A303
Rolfe SW	A303 derivative with lead carbonate added	NA	1 YR	DNH	B	n	STD-3	75%	69.6	1,050	**760**	ND	**2.39**	ND	**0.14**	ND	30	NM	#3ARolfemade1.1K PB A303
Rolfe SW	A303 derivative with lead carbonate added	NA	1 YR	DNH	B	n	STD-4	75%	71.7	390	**241**	ND	**2.42**	ND	**0.14**	ND	20	NM	#4ARolfemade0.3K PB A303
Rolfe SW	A303 derivative with lead carbonate added	NA	1 YR	DNH	B	n	STD-5	75%	71.3	87	**76.8**	ND	**2.32**	ND	**0.14**	ND	ND	NM	#5ARolfemade0.1K PB A303

DNH = do not have the data
NM = not measured
ND = Not detected
U = less than or equal to reporting limit

[A] NOTE: sample already dry
[B] = Depends on humidity, temperature, and film thickness
[C] Estimated Dry Time based on MSDS or tech specs
* = estimate based on summation of weight % solids from composition information on MSDS.

Appendix B: Paint Thickness and XRF Data

Table B-1. XRF-measured lead concentrations and paint thickness for metal strip with lab-measured 13,600 mg/kg underlying lead paint concentration.

13,600 mg/kg underlying lead concentration			
Location		**Lead (ppm)**	**Paint Thickness* (mils)**
Leaded paint	1	12,000	0.020
	2	5,150	0.035
	3	11,100	0.037
	4	13,600	0.028
	5	12,100	0.030
Layer 1	6	1,252	0.041
	7	2,110	0.047
	8	2,130	0.051
	9	406	0.054
	10	4,280	0.058
Layer 2	11	720	0.067
	12	547	0.084
	13	780	0.078
	14	1,390	0.060
	15	490	0.083
Layer 3	16	750	0.067
	17	162	0.097
	18	239	0.083
	19	500	0.060
	20	650	0.073
Layer 4	21	155	0.086
	22	370	0.071
	23	440	0.087
	24	196	0.081
	25	204	0.092
Layer 5	26	510	0.076
	27	117	0.091
	28	170	0.088
	29	190	0.083
	30	100	0.100

*Paint thickness is the thickness of the lead paint applied plus the thickness of subsequent overlying layers of non-leaded paint.

Table B-2. XRF-measured lead concentrations and paint thickness for metal strip with lab-measured 2,170 mg/kg underlying lead paint concentration.

2,170 mg/kg underlying lead concentration			
Location		**Lead (ppm)**	**Paint Thickness* (mils)**
Leaded paint	1	3,020	0.008
	2	1,743	0.014
	3	2,570	0.009
	4	2,670	0.007
	5	3,010	0.009
Layer 1	6	540	0.029
	7	225	0.027
	8	370	0.028
	9	330	0.034
	10	360	0.028
Layer 2	11	110	0.053
	12	150	0.052
	13	160	0.056
	14	110	0.055
	15	75	0.053
Layer 3	16	33	0.068
	17	80	0.072
	18	55	0.071
	19	50	0.067
	20	80	0.059

*Paint thickness is the thickness of the lead paint applied plus the thickness of subsequent overlying layers of non-leaded paint.

Table B-3. XRF-measured lead concentrations and paint thickness for metal strip with lab-measured 760 mg/kg underlying lead paint concentration.

760 mg/kg underlying lead concentration			
Location		**Lead (ppm)**	**Paint Thickness* (mils)**
Leaded paint	1	624	0.022
	2	1,410	0.030
	3	1,000	0.008
	4	910	0.009
	5	1,360	0.012
Layer 1	6	510	0.033
	7	610	0.048
	8	83	0.052
	9	400	0.045
	10	150	0.044
Layer 2	11	220	0.064
	12	60	0.070
	13	33	0.059
	14	220	0.050
	15	30	0.068
Layer 3	16	40	0.060
	17	30	0.076
	18	29	0.074
	19	46	0.055
	20	40	0.067

*Paint thickness is the thickness of the lead paint applied plus the thickness of subsequent overlying layers of non-leaded paint.

Table B-4. XRF-measured lead concentrations and paint thickness for metal strip with lab-measured 241 mg/kg underlying lead paint concentration.

241 mg/kg underlying lead concentration			
Location		**Lead (ppm)**	**Paint Thickness* (mils)**
Leaded paint	1	600	0.014
	2	460	0.017
	3	460	0.016
	4	530	0.018
	5	400	0.017
Layer 1	6	70	0.035
	7	60	0.041
	8	50	0.035
	9	160	0.037
	10	50	0.044
Layer 2	11	40	0.054
	12	30	0.056
	13	60	0.061
	14	30	0.054
	15	30	0.061
Layer 3	16	21	0.070
	17	25	0.069
	18	14	0.072
	19	10	0.074
	20	10	0.069

*Paint thickness is the thickness of the lead paint applied plus the thickness of subsequent overlying layers of non-leaded paint.

Table B-5. XRF-measured lead concentrations and paint thickness for metal strip with lab-measured 77 mg/kg underlying lead paint concentration.

77 mg/kg underlying lead concentration			
Location		Lead (ppm)	Paint Thickness* (mils)
Leaded paint	1	190	0.029
	2	200	0.020
	3	109	0.026
	4	108	0.031
	5	380	0.025
Layer 1	6	38	0.043
	7	60	0.044
	8	60	0.050
	9	50	0.052
	10	50	0.044
Layer 2	11	30	0.066
	12	16	0.068
	13	18	0.069
	14	30	0.071
	15	60	0.058
Layer 3	16	20	0.100
	17	40	0.072
	18	20	0.072
	19	30	0.083
	20	15	0.071

*Paint thickness is the thickness of the lead paint applied plus the thickness of subsequent overlying layers of non-leaded paint.